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(54) **DIRECT ROUTING OF COMMUNICATION SESSIONS FOR MOBILE IP COMMUNICATION END POINTS**

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(51) **Int. Cl.**

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H04L 12/715	(2013.01)
H04W 8/12	(2009.01)
H04W 76/02	(2009.01)
H04W 40/02	(2009.01)
H04L 29/12	(2006.01)
H04W 8/08	(2009.01)

(52) **U.S. Cl.**

CPC ***H04W 40/20*** (2013.01); ***H04L 45/04*** (2013.01); ***H04W 8/12*** (2013.01); ***H04W 40/02*** (2013.01); ***H04W 76/023*** (2013.01); ***H04W 80/04*** (2013.01); *H04L 61/157* (2013.01); *H04L 61/1511* (2013.01); *H04W 8/085* (2013.01)

(58) **Field of Classification Search**

None

See application file for complete search history.

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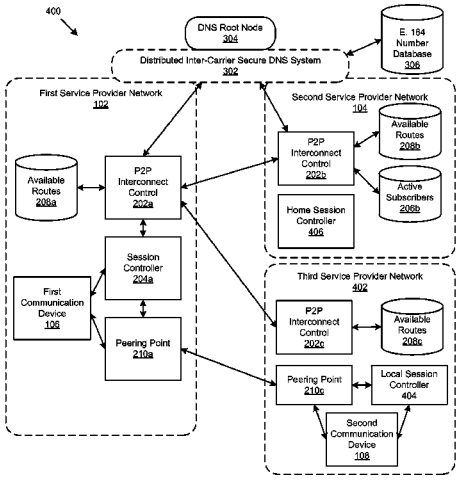
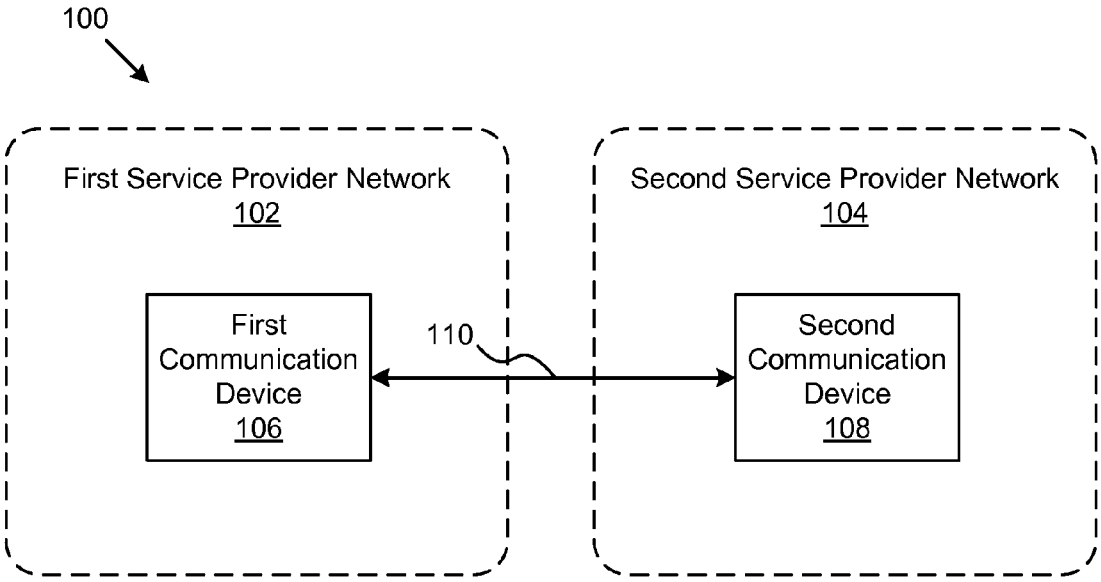
(57) **ABSTRACT**

Embodiments of methods and systems for direct routing of communication sessions for mobile IP communication end points are presented. The methods may be implemented in a service provider network. In one embodiment, a method includes receiving, on a first service provider network, a request for access to a target communication device, the target communication device being associated with a second service provider network. The method may also include receiving an indicator, from the second service provider network, that the target communication device is roaming on a third service provider network. Additionally, the method may include establishing a peer-to-peer communication link with the target communication device on the third service provider network by a direct peer-to-peer interconnection process.

21 Claims, 9 Drawing Sheets

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First Service Provider Network
102
Second Service Provider Network
104
First
Communication
Device
106
110
Second
Communication
Device
108

FIG. 1

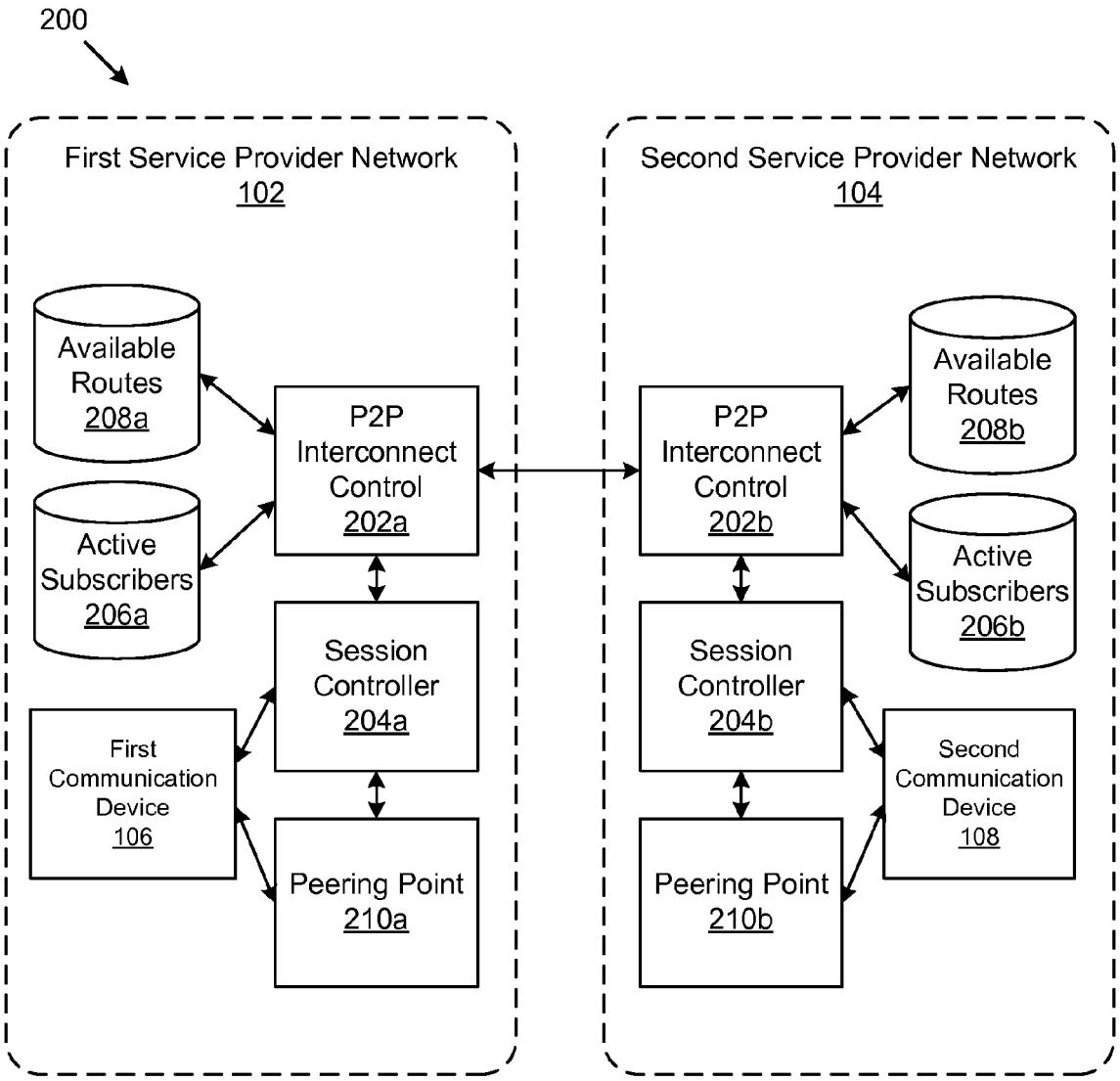

200
First Service Provider Network
102
Available Routes
208a
Active Subscribers
206a
P2P Interconnect Control
202a
Session Controller
204a
First Communication Device
106
Peering Point
210a
Second Service Provider Network
104
Available Routes
208b
Active Subscribers
206b
P2P Interconnect Control
202b
Session Controller
204b
Second Communication Device
108
Peering Point
210b

FIG. 2

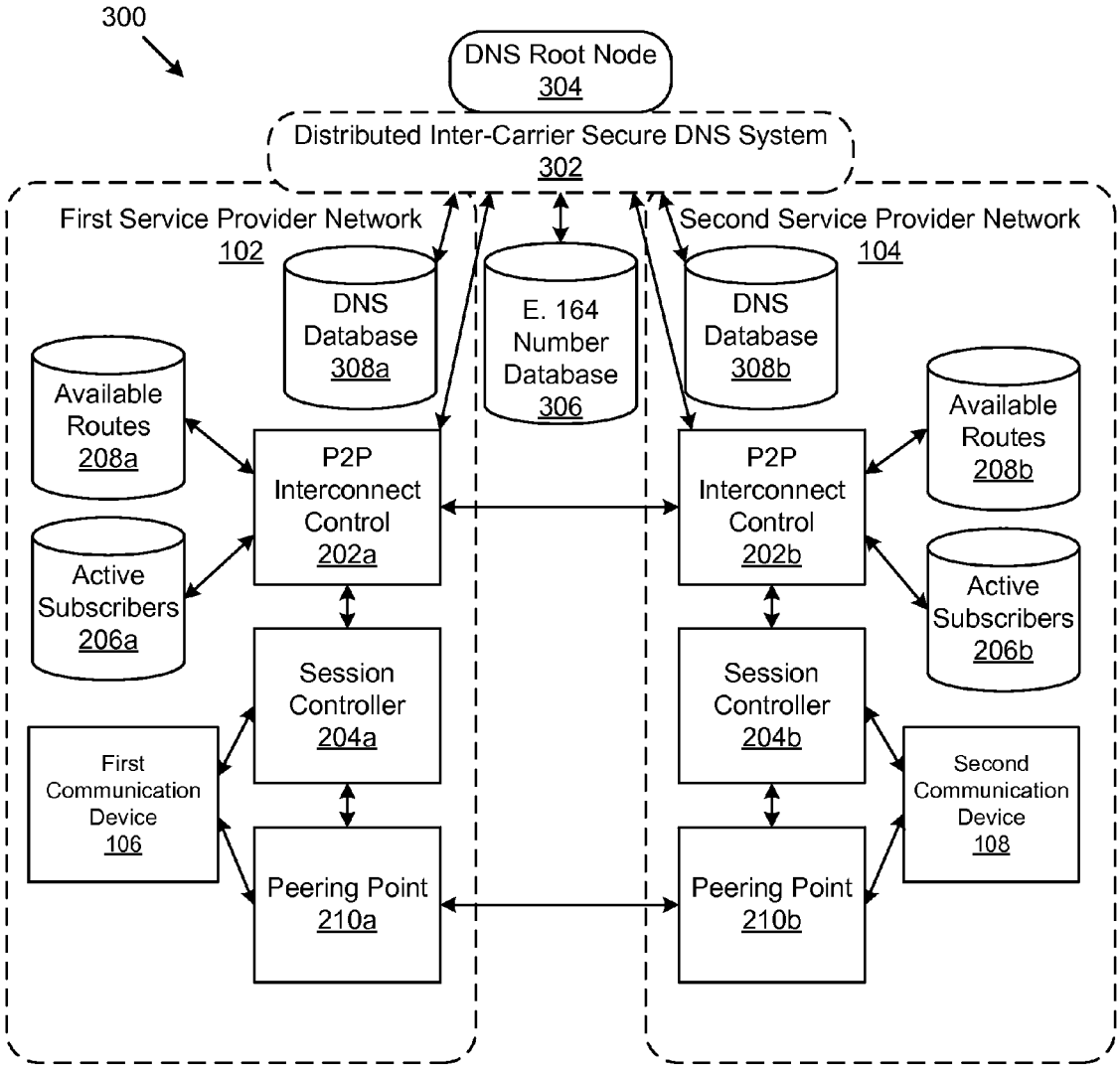

300
DNS Root Node
304
Distributed Inter-Carrier Secure DNS System
302
First Service Provider Network
102
Second Service Provider Network
104
DNS
Database
308a
E. 164
Number
Database
306
DNS
Database
308b
Available
Routes
208a
Available
Routes
208b
P2P
Interconnect
Control
202a
P2P
Interconnect
Control
202b
Active
Subscribers
206a
Active
Subscribers
206b
Session
Controller
204a
Session
Controller
204b
First
Communication
Device
106
Second
Communication
Device
108
Peering Point
210a
Peering Point
210b

FIG. 3

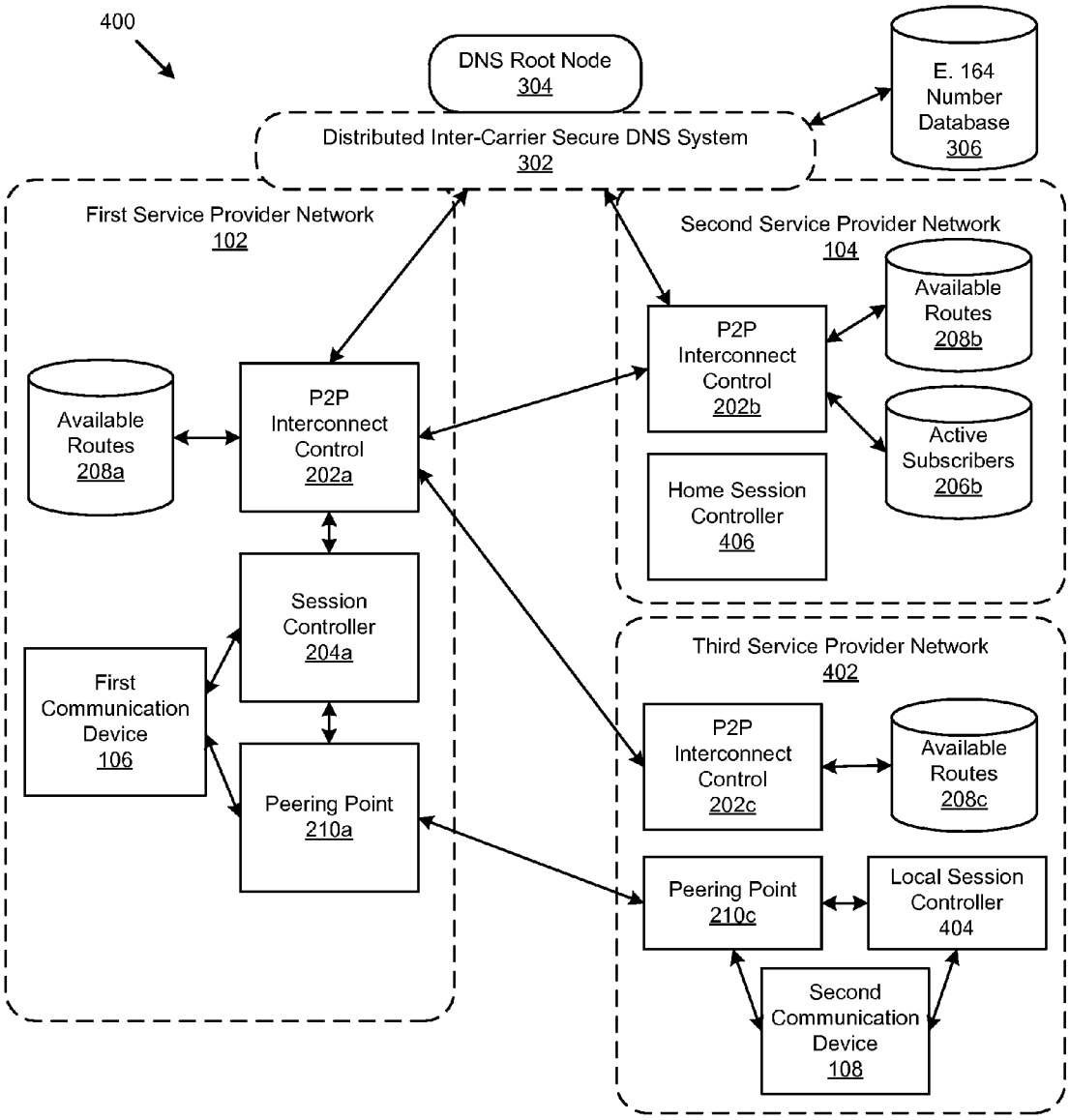

400
DNS Root Node
304
E. 164
Number
Database
306
Distributed Inter-Carrier Secure DNS System
302
First Service Provider Network
102
Second Service Provider Network
104
Available
Routes
208b
P2P
Interconnect
Control
202b
Available
Routes
208a
P2P
Interconnect
Control
202a
Active
Subscribers
206b
Home Session
Controller
406
Session
Controller
204a
Third Service Provider Network
402
First
Communication
Device
106
P2P
Interconnect
Control
202c
Available
Routes
208c
Peering Point
210a
Peering Point
210c
Local Session
Controller
404
Second
Communication
Device
108

FIG. 4

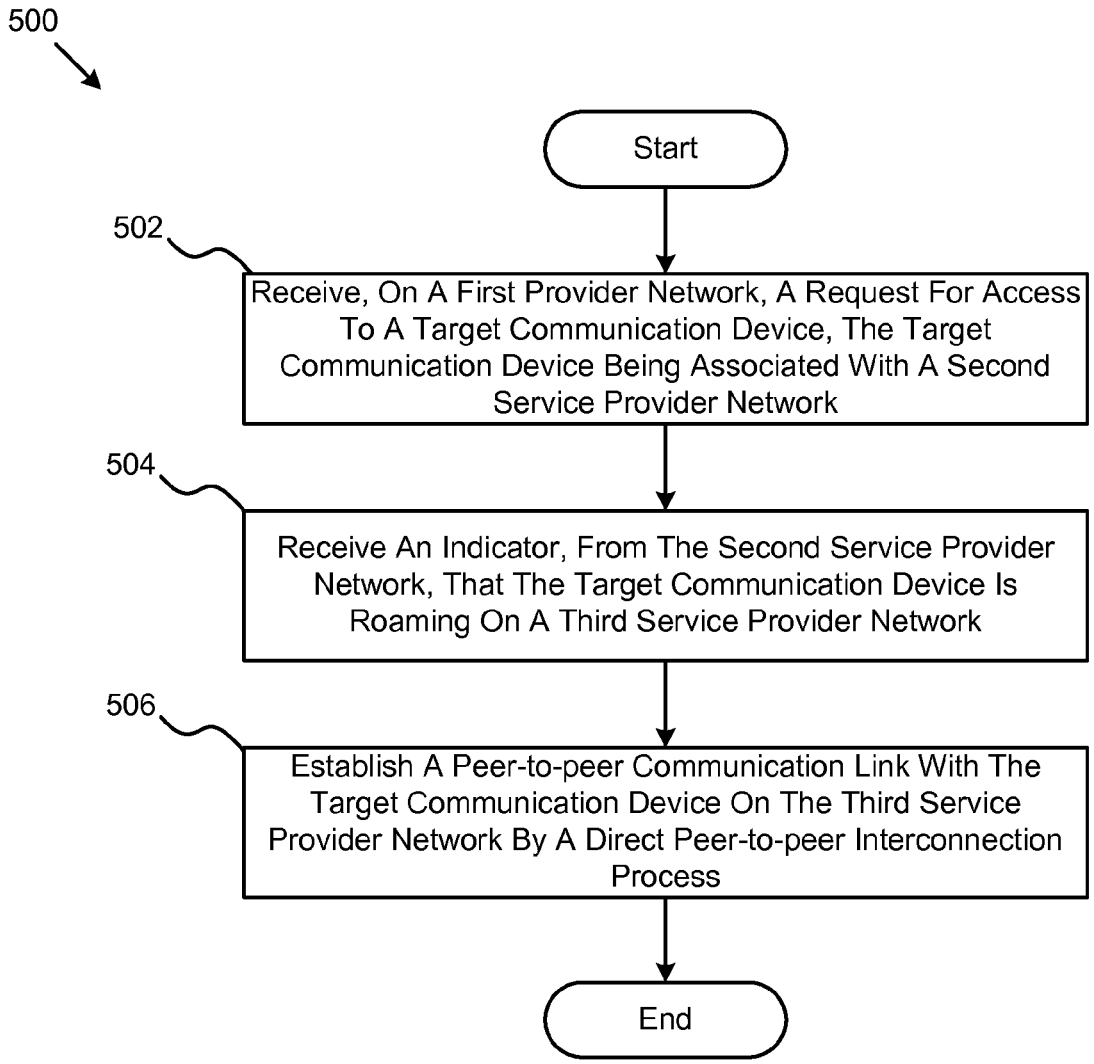

500
Start
502
Receive, On A First Provider Network, A Request For Access To A Target Communication Device, The Target Communication Device Being Associated With A Second Service Provider Network
504
Receive An Indicator, From The Second Service Provider Network, That The Target Communication Device Is Roaming On A Third Service Provider Network
506
Establish A Peer-to-peer Communication Link With The Target Communication Device On The Third Service Provider Network By A Direct Peer-to-peer Interconnection Process
End

FIG. 5

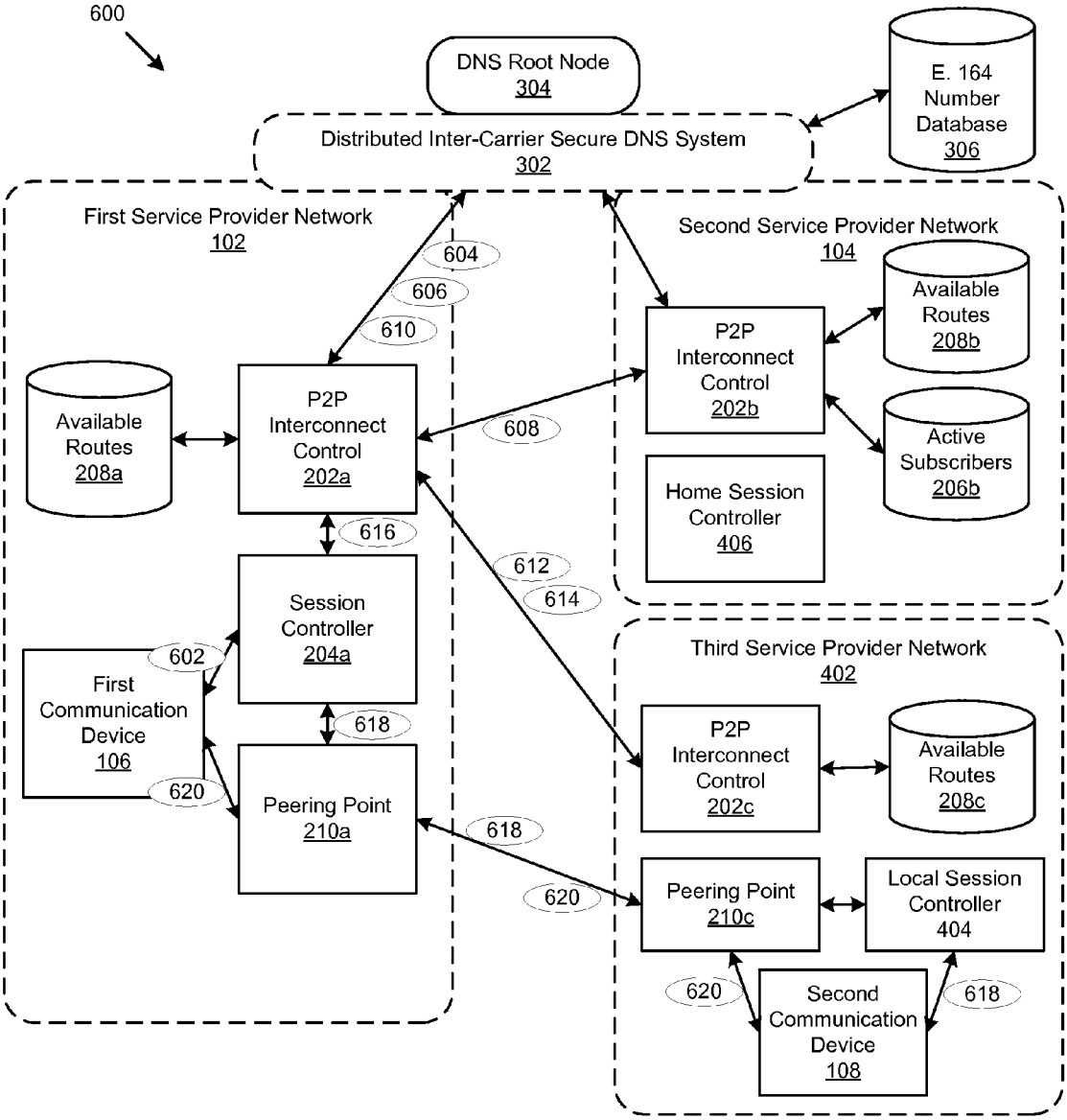

600
DNS Root Node
304
E. 164
Number
Database
306
Distributed Inter-Carrier Secure DNS System
302
First Service Provider Network
102
Second Service Provider Network
104
604
606
610
Available
Routes
208a
P2P
Interconnect
Control
202a
608
P2P
Interconnect
Control
202b
Available
Routes
208b
Active
Subscribers
206b
Home Session
Controller
406
616
612
614
Session
Controller
204a
602
First
Communication
Device
106
618
620
Peering Point
210a
Third Service Provider Network
402
P2P
Interconnect
Control
202c
Available
Routes
208c
618
620
Peering Point
210c
Local Session
Controller
404
620
Second
Communication
Device
108
618

FIG. 6

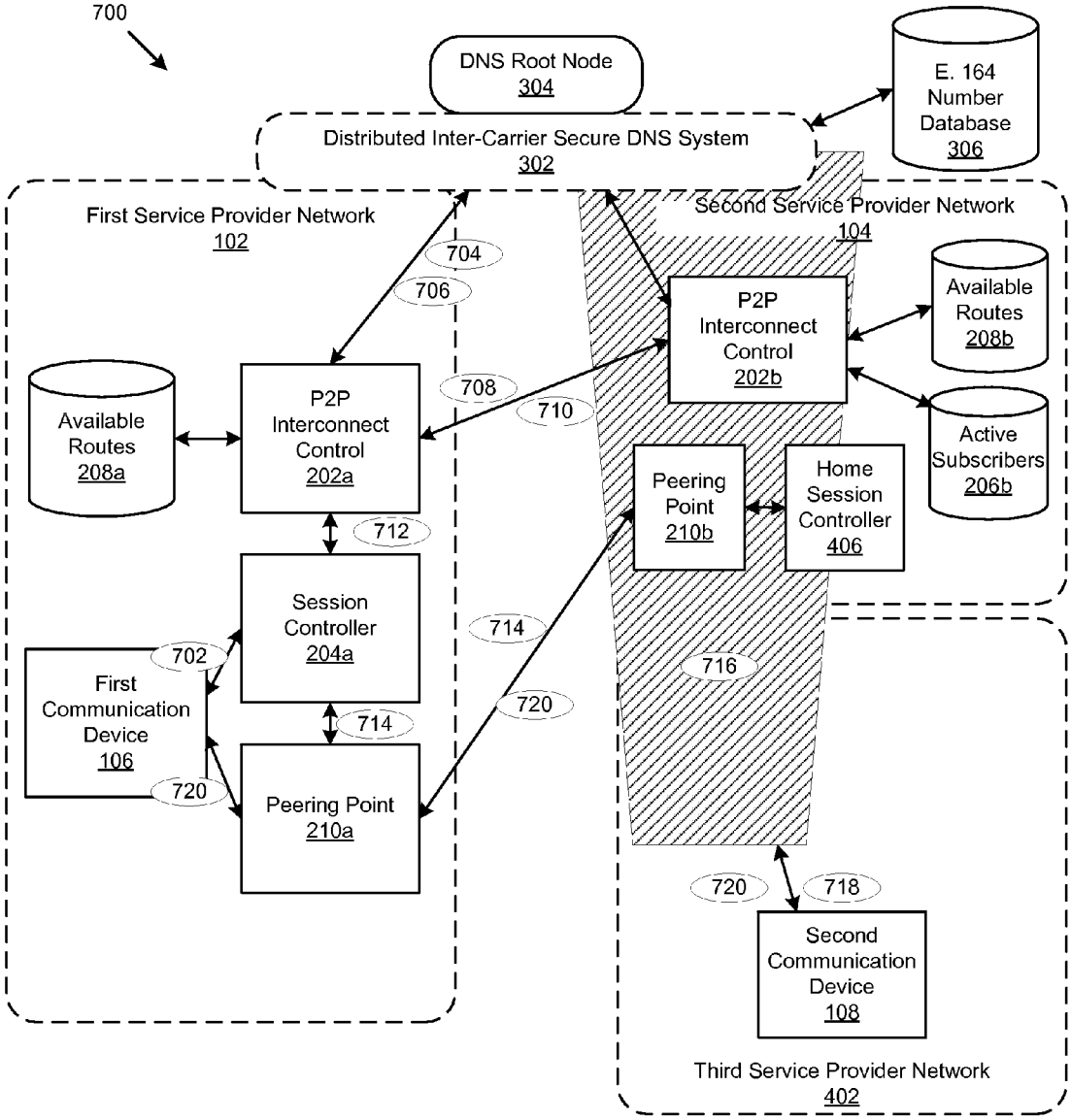

700
DNS Root Node
304
E. 164
Number
Database
306
Distributed Inter-Carrier Secure DNS System
302
First Service Provider Network
102
Second Service Provider Network
104
704
706
P2P
Interconnect
Control
202b
Available
Routes
208b
Available
Routes
208a
P2P
Interconnect
Control
202a
708
710
Active
Subscribers
206b
Peering
Point
210b
Home
Session
Controller
406
712
Session
Controller
204a
714
716
702
First
Communication
Device
106
720
714
720
Peering Point
210a
720
718
Second
Communication
Device
108
Third Service Provider Network
402

FIG. 7

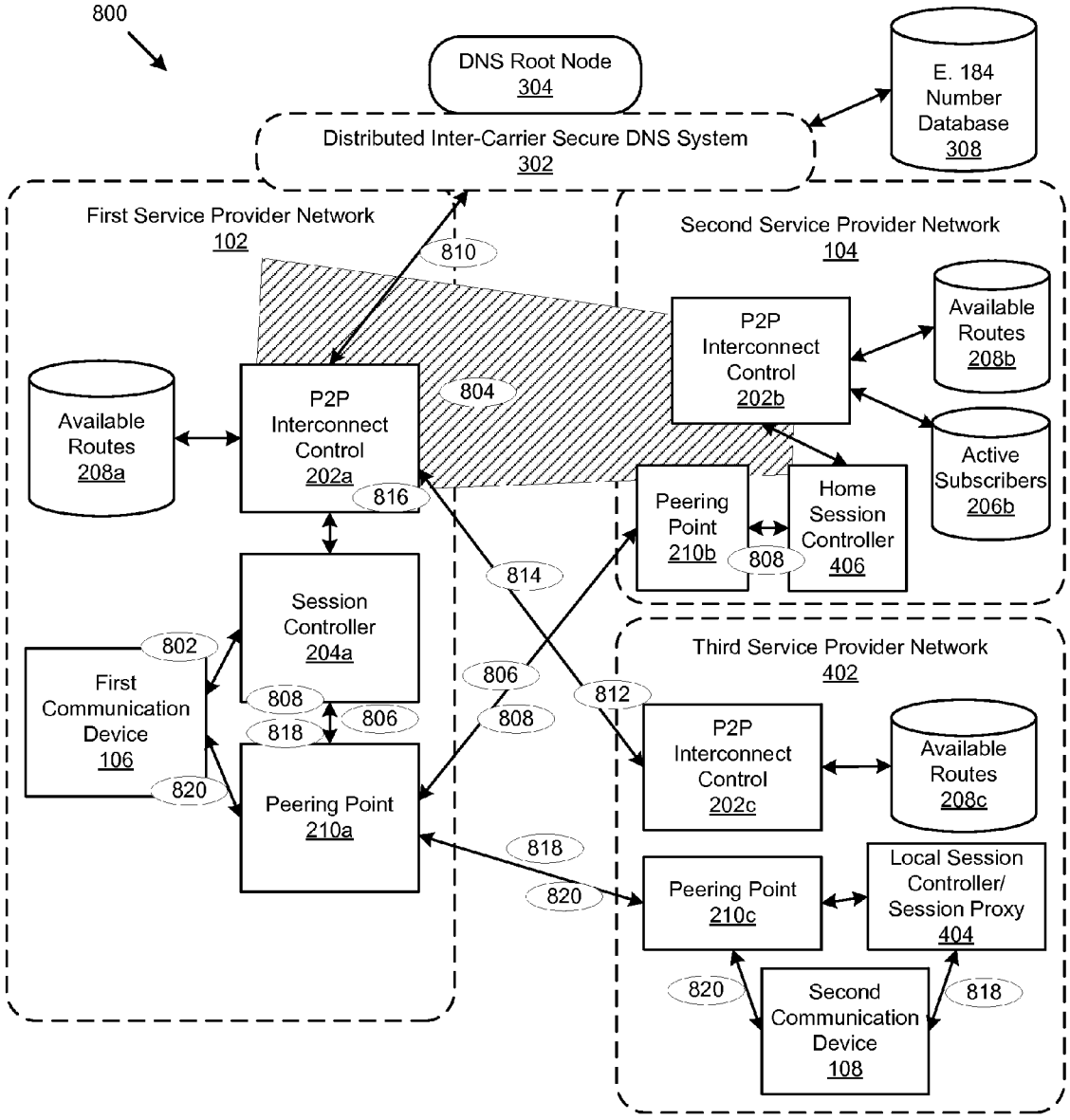
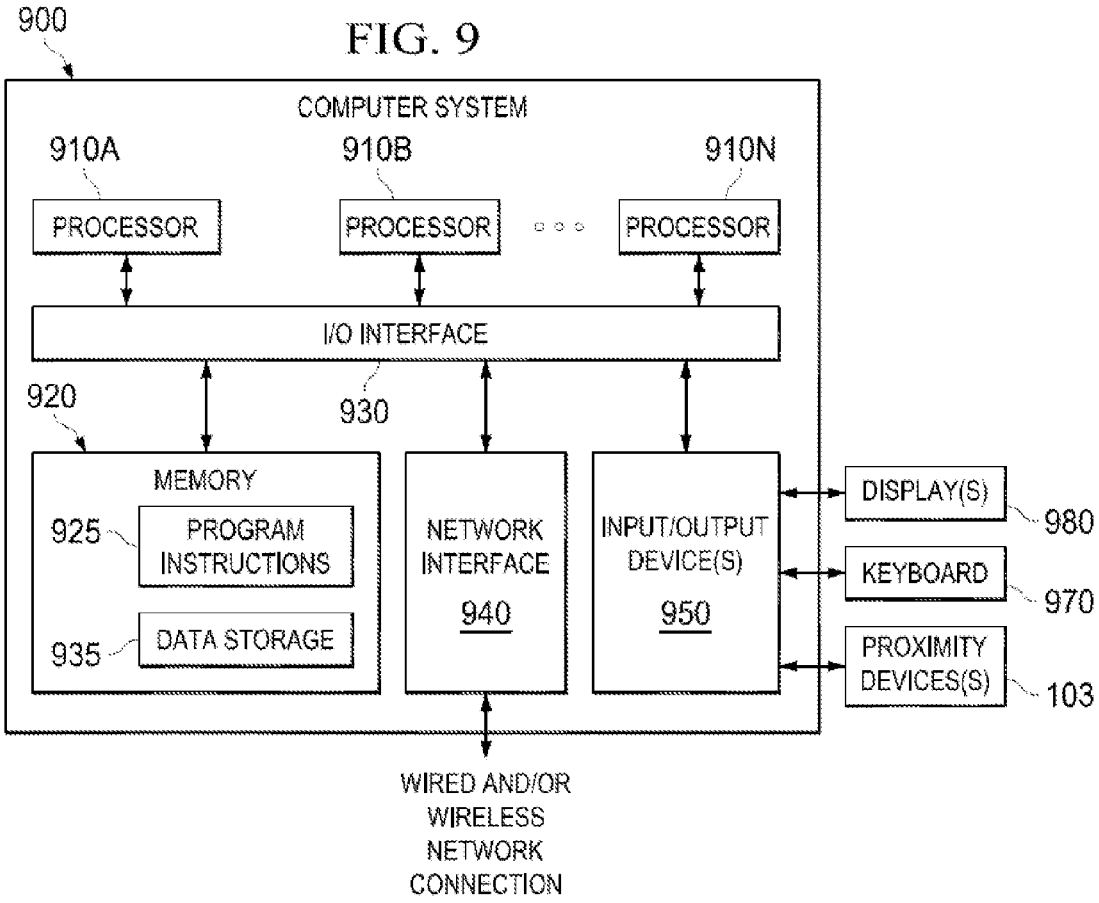

800
DNS Root Node
304
E. 184
Number
Database
308
Distributed Inter-Carrier Secure DNS System
302
First Service Provider Network
102
Second Service Provider Network
104
Third Service Provider Network
402
810
804
816
814
812
806
808
818
820
802
Available
Routes
208a
P2P
Interconnect
Control
202a
Session
Controller
204a
First
Communication
Device
106
Peering Point
210a
P2P
Interconnect
Control
202b
Available
Routes
208b
Active
Subscribers
206b
Peering
Point
210b
Home
Session
Controller
406
P2P
Interconnect
Control
202c
Available
Routes
208c
Peering Point
210c
Local Session
Controller/
Session Proxy
404
Second
Communication
Device
108

FIG. 8

FIG. 9


900
COMPUTER SYSTEM
910A
910B
910N
PROCESSOR
PROCESSOR
PROCESSOR
I/O INTERFACE
920
930
MEMORY
925
PROGRAM INSTRUCTIONS
935
DATA STORAGE
NETWORK INTERFACE
940
INPUT/OUTPUT DEVICE(S)
950
DISPLAY(S)
980
KEYBOARD
970
PROXIMITY DEVICES(S)
103
WIRED AND/OR WIRELESS NETWORK CONNECTION

DIRECT ROUTING OF COMMUNICATION SESSIONS FOR MOBILE IP COMMUNICATION END POINTS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is related to U.S. patent application Ser. No. 13/838,769, entitled "Peer-to-Peer Interconnection Between Service Providers," filed on Mar. 15, 2013 and issued as U.S. Pat. No. 9,270,516 on Feb. 23, 2016, and Ser. No. 13/841,185, entitled "Determining Peer-to-Peer Communication Paths between Service Providers," filed on Mar. 15, 2013 and issued as U.S. Pat. No. 9,042,235 on May 26, 2015, each of which are incorporated herein by reference in their entirety.

TECHNICAL FIELD

This disclosure relates generally to telecommunications, and more specifically, to methods and systems for direct routing of communication sessions for mobile IP communication end points.

BACKGROUND

The following discussion sets forth the inventors' own knowledge of certain technologies and/or problems associated therewith. Accordingly, this discussion is not an admission of prior art, and it is not an admission of the knowledge available to a person of ordinary skill in the art.

The telecommunications market includes many different service providers, each typically offering compatible communications services. Compatibility is often required so that customers of one service provider can communicate with friends, family, or other end users who may be customers of another service provider. Although service providers typically offer services that are compatible with other service provider networks, there has not conventionally been a direct connect option between users of diverse service provider networks.

One prior solution for handling interfaces between different service provider networks is conventionally handled by a third party intermediary. The third party intermediary would typically establish an interconnect agreement with many different service providers, and then provide connection services between users of the different service provider networks.

In certain situations, a communication will hop between multiple third parties or across multiple carriers in order to find an agreed path between communication endpoints. In legacy systems, a call may be routed through several carriers before connecting between the end users. Each connection may include connection and/or termination fees. These prior systems become very complex and expensive.

With existing IP interconnection implementations in mobile roaming scenarios, control signaling and media is routed through the home networks so that services can be applied and the home network can make the decision on whether or not the media should be optimally routed.

SUMMARY

Embodiments of methods and systems for direct routing of communication sessions for mobile IP communication end points are presented. The methods may be implemented in a service provider network. In one embodiment, a method includes receiving, on a first service provider network, a request for access to a target communication device, the target communication device being associated with a second service provider network. The method may also include receiving an indicator, from the second service provider network, that the target communication device is roaming on a third service provider network. Additionally, the method may include establishing a peer-to-peer communication link with the target communication device on the third service provider network by a direct peer-to-peer interconnection process.

BRIEF DESCRIPTION OF THE DRAWINGS

Reference will now be made to the accompanying drawings, wherein:

FIG. **1** is a block diagram illustrating one embodiment of a system for direct routing of communication sessions for mobile IP communication end points.

FIG. **2** is a block diagram illustrating another embodiment of a system for direct routing of communication sessions for mobile IP communication end points.

FIG. **3** is a block diagram illustrating another embodiment of a system for direct routing of communication sessions for mobile IP communication end points.

FIG. **4** is a block diagram illustrating another embodiment of a system for direct routing of communication sessions for mobile IP communication end points.

FIG. **5** is a flowchart of a method for direct routing of communication sessions for mobile IP communication end points.

FIG. **6** is system state diagram illustrating one embodiment of a method for direct routing of communication sessions for mobile IP communication end points.

FIG. **7** is system state diagram illustrating one embodiment of a method for direct routing of communication sessions for mobile IP communication end points.

FIG. **8** is system state diagram illustrating one embodiment of a method for direct routing of communication sessions for mobile IP communication end points.

FIG. **9** is a block diagram of a computer system configured to implement various systems and methods described herein according to some embodiments.

DETAILED DESCRIPTION

Embodiments disclosed herein are directed generally to methods and systems for direct routing of communication sessions for mobile IP communication end points. According to certain embodiments, the home network of the roaming endpoint can make the decision to directly route the control signaling only or both control signaling and media directly to the visited network thereby creating a more optimal route. Accordingly, certain embodiments provide methods and systems for direct routing for interconnecting IP communication traffic among carriers where endpoints are roaming outside of the home network.

Beneficially, such an embodiment may create a more efficient and cost effective means of IP mobile traffic routing, especially in roaming scenarios. Additionally, certain embodiments may achieve major improvements in efficiency of interconnecting and handling mobile signaling and media traffic among carriers, especially in roaming scenarios. The Peer-to-Peer Interconnect system enables an optimal direct routing decision to be made in a peer-to-peer configuration amongst service providers involved in a roaming scenario as well as to determine how to reach the proper

point in the visited network service provider's network. The roaming system described herein also generates records for billing as part of the peer-to-peer roaming session sequence.

This invention eliminates the requirement to route mobile traffic (signalling and/or media) through the home carrier's network in roaming scenarios inherent in existing approaches.

The term "telecommunications," as used herein, is intended to encompass voice communications or telephony, as well as other forms of communications (e.g., video communications, videoconferencing, instant messaging or IM, Short Messaging Service or SMS, emails, etc.) that may take place electronically, for example, over wireless networks, circuit-switched networks, packet-switched networks, or any combination thereof.

FIG. **1** is a block diagram illustrating one embodiment of a system for peer-to-peer interconnection between service providers. In one embodiment, the system **100** includes a first service provider network **102** and a second service provider network **104**. Examples of service providers include, but are not limited to, AT&T®, Verizon®, Vodafone™, etc. In one embodiment, the provider networks **102** may be the networks may be packet-switched, circuit-switched, wireless, or any combination thereof. In general embodiments, a first communication device **106** on the first service provider network **102** may be configured to communicate with a second communication device **108** on a second service provider network **104** over a peer-to-peer communication interconnection path **110** between the first service provider network **102** and the second service provider network **104**. In one embodiment, first communication device **106** and second communication device **108** are user communication devices (e.g., telephones, mobile phones, laptops, tablet computers, etc.) for a user who is a subscriber of the first service provider network **102** and second service provider network **104** respectively. As used herein, the term "foreign service provider" means a different service provider network than one that a user subscribes to (e.g., second service provider network **104** as to first communication device **106** in FIGS. **1-2**).

Beneficially, such an embodiment may enable the first communication device **106** to initiate, negotiate, and carry out communications with the second communication device **108** without requiring a central route lookup function or an administrator. More specifically, the present embodiments may eliminate use of centralized or third-party interconnection sources, and the associated expenses of routing and relating number lookup information. Thus, use of such centralized or third-party interconnection sources by the service providers **102**,**104** is not required for enabling communication between devices **106**,**108**. Further benefits may include elimination of class 4 interconnection elements in existing network infrastructures.

FIG. **2** is a block diagram illustrating another embodiment of a system **200** for peer-to-peer interconnection between service providers. As in FIG. **1**, system **200** may also include a first service provider network **102** and a second service provider network **104**, each providing user connectivity to a first communication device **106** and second communication device **108** respectively. In addition, the system **200** may include a peer-to-peer interconnect control **202***a-b*, and a session controller **204***a-b*.

Peer-to-peer interconnect control **202** may be configured to access and query active subscribers database **206** and available routes database **208**. In one embodiment, each of the first service provider network **102** and the second service provider network **104** each maintain an active subscribers database **206***a,b* and an available routes database **208***a,b* respectively for storing connectivity information for the local network. For example, an identifier associated with first communication device **106** may be stored in active subscribers database **206***a*, which is maintained by first service provider network **102**. Similarly, available routes database **208***a* may store a listing of available connection routes for accessing first communication device **106**. Likewise, the active subscribers database **206***b* and available routes database **208***b* maintained by second service provider network **104** may include information for connecting to second communication device **108**.

Peer-to-Peer interconnect control **202***a* may handle coordination of peer-to-peer communication routing for all devices on first service provider network **102**. In one embodiment, peer-to-peer interconnect control **202***a* may be a communication interface to second service provider network **104** and other service provider networks. Session controller **204***a* may be in communication with peer-to-peer control **202***a*, and may serve as an internal interface to first communication device **106**. Peering point **210***a* may handle device-to-device communication between the first communication device **106** and the second communication device **108** once the peer-to-peer link has been negotiated and routed by peer-to-peer interconnect control **202***a*.

Thus, in a simplified view, the peer-to-peer interconnect control **202***a* negotiates and routes peer-to-peer communication links between service provider networks, session controller **204***a* handles intra-network interfaces between devices, and peering point **210***a* handles content communication between service provider networks once the link has been established by peer-to-peer interconnect control **202***a*. One of ordinary skill in the art will recognize that each of the corresponding devices in the second service provider network have a similar and corresponding function.

FIG. **3** is a block diagram illustrating another embodiment of a system **300** for peer-to-peer interconnection between service providers **102-104**. The embodiment of FIG. **3** illustrates additional components which may facilitate peer-to-peer interconnection between service provider networks. In addition to the components described in FIGS. **1-2**, the embodiment of FIG. **3** includes a Distributed Inter-Carrier Secure DNS System (DICSDS) **302**, a DNS root node **304**, and an E.164 Number (ENUM) database **306**. In addition, each service provider network may include a DNS database **308***a,b* respectively.

In one embodiment, DICSDS **302** may be a common DNS system among service providers and E.164 providers. In one embodiment, DNS name resolution data may be controlled by the owning service provider via their local segment of the DICSDS **302**. In one embodiment, DICSDS **302** may facilitate address lookup for interface nodes within service provider networks. For example, peer-to-peer interconnect control **202***a* on the first service provider network **102** may query DICSDS **302** to determine an address for P2P interconnect control **202***b* on the second service provider network **104** in order to initiate P2P route negotiations.

ENUM database **306** may contain a commonly accessible list of ENUM identifiers, which DICSDS **302** may access in response to a query from a P2P interconnect control **202**. ENUM database **306** enables E.164 number to Service Provider mapping via DNS. DNS root node **304** enables the first service provider **102** and the second service provider **104** to create a common DNS system, such that both service providers have access to common address data.

FIG. **4** illustrates a further embodiment of a system **400** for direct routing of communication sessions for mobile IP

communication end points. System **400** may include the components of first service provider network **102** and second service provider network **104** substantially as described above with reference to FIG. **3**. In addition, FIG. **4** may include a third service provider network **402**.

Third service provider network **402** may also include P2P interconnect control **202***c*, available routes database **208***c*, peering point **210***c* and a local session controller (or session proxy) **404**. In one embodiment, second communication device **108** may be configured to roam on third service provider network **402** and communicate with peering point **210***c* as well as local session controller **404**.

FIG. **5** illustrates one embodiment of a method **500** for direct routing of communication sessions for mobile IP communication end points. The method **500** may start when session controller **204***a* receives a request, as shown at block **502**, from first communication device **106** to access second communication device **108** which has roamed from its home network (second service provider network **104**) to a third service provider network **402**. Following embodiments described herein, as well as embodiments described in the co-pending related applications set forth above, the P2P interconnect control **202***a* may receive an indicator, from the second service provider network **104**, that the second communication device **108** is roaming on the third service provider network **402** as shown in block **504**. In response, the P2P interconnect control **202***a* may establish a peer-to-peer communication link with the second **108** communication device on the third service provider network **402** by a direct peer-to-peer interconnection process as shown at block **506**. In one embodiment, the direct peer-to-peer interconnection process may be established directly between the first service provider network **102** and the third service provider network **402**. Alternatively, a direct peer-to-peer interconnection process may be established directly between the first service provider network **102** and the second service provider network **104**, and a second direct peer-to-peer interconnection process may be established directly between the second service provider network **104** and the third service provider network **402**, thus establishing a link between first communication device **106** and second communication device **108**. In still further embodiments, hyprid connections may be established as described in greater detail below.

FIG. **6** illustrates one embodiment of a method **600** for direct routing of communication sessions for mobile IP communication end points. In one embodiment the method **600** starts when first communication device **106** initiates, at state **602**, a session to second communication device **108**. In the depicted embodiment, first communication device **106** is a subscriber on first service provider network **102** and second communication device is a subscriber of the second service provider network **104**, but roaming on third service provider network **402** at the time of the request. More specifically, first communication device **106** may send a request to session controller **204***a* as shown by state **602**.

At state **604**, P2P interconnect control **202***a* may perform an ENUM query to look up the identity of the home network of second communication device **108** (e.g., second service provider **104**). Additionally, as shown at state **606**, the P2P interconnect control **202***a* may query the DNS route server **302** to obtain the Name Server address where the address of P2P interconnect control **202***b* for second service provider network **104** can be obtained, and obtain the node address for P2P interconnect control **202***b*.

At state **608**, P2P interconnect control **202***a* of the first service provider network **102** may contact P2P interconnect control **202***b* of the second service provider network **104** to confirm that P2P interconnect services are supported by second service provider network **104**. In the embodiment described, however, P2P interconnect control **202***a* may obtain redirect information due to roaming through query of Active Subscriber Database **208***b*.

At state **610**, P2P interconnect control **202***a* may then query DNS server **302** to obtain the address for the third service provider network **402** and then contact P2P interconnect controller **202***c* on third service provider network **402** as shown at state **612**.

At state **614**, P2P interconnect control **202***c* to may query available routes database **208***c* to identify available routes to second communication device **108** and return the available routes to P2P interconnect control **202***a* on the first service provider network **102**. At state **616**, P2P interconnect control **202***a* may use the available route information to select a route to peering point **210***c*, which may render a Session Detail Record (SDR) for accounting use at the end of the session. At state **618**, session controller **204***a* may establish signaling between peering point **210***a* and remote peering point **210***c* using the selected route. At state **620**, a media path may be established between peering point **210***a* and peering point **210***c*, which enables the first communication device **106** to communicate content with second communication device **108** while roaming on third service provider network **402**.

FIG. **7** illustrates an embodiment of a method **700** for direct routing of communication sessions for mobile IP communication end points, where the target communication device's home network (e.g., second service provider network **104**) handles signaling interface and media interface with first service provider network **102**.

In one embodiment the method **700** starts when first communication device **106** initiates, at state **702**, a session to second communication device **108**. In the depicted embodiment, first communication device **106** is a subscriber on first service provider network **102** and second communication device is a subscriber of the second service provider network **104**, but roaming on third service provider network **402** at the time of the request. More specifically, first communication device **106** may send a request to session controller **204***a* as shown by state **702**.

At state **704**, P2P interconnect control **202***a* may perform an ENUM query to look up the identity of the home network of second communication device **108** (e.g., second service provider **104**). Additionally, as shown at state **706**, the P2P interconnect control **202***a* may query the DNS route server **302** to obtain the Name Server address where the address of P2P interconnect control **202***b* for second service provider network **104** can be obtained, and obtain the node address for P2P interconnect control **202***b*.

At state **708**, P2P interconnect control **202***a* of the first service provider network **102** may contact P2P interconnect control **202***b* of the second service provider network **104** to confirm that P2P interconnect services are supported by second service provider network **104**. At state **710**, P2P interconnect control **202***b* may return routing information for establishing a link between peering point **210***a* and peering point **210***b* as shown at states **712** and **714**, which operate normally.

At state **716**, second service provider network **104** establishes a second peer-to-peer link with third service provider network **402** and signaling links as well as media links are established. The signaling and media are forwarded by second service provider network **104** to first service provider **102** as shown at state **718** and **720**. In such an embodiment,

the second service provider may maintain control of communications with second communication device **108** in a way that may be transparent to first communication device **106**.

FIG. **8** illustrates an embodiment of a method **800** for direct routing of communication sessions for mobile IP communication end points, where the target communication device's home network (e.g., second service provider network **104**) handles signaling interface but a direct media interface between first service provider network **102** and third service provider network **402** is established.

In the depicted embodiment, first communication device **106** is a subscriber on first service provider network **102** and second communication device is a subscriber of the second service provider network **104**, but roaming on third service provider network **402** at the time of the request. More specifically, first communication device **106** may send a request to session controller **204***a* as shown by state **802**.

At state **804**, a signaling interface between first service provider network **102** and second service provider network **104** may be established according to the various methods previously described. Once the signaling interface is established, the peering point **210***a* and peering point **210***b* may be in communication at state **806**. Due to the subscriber roaming the home session control **406** loops the control signalling back to the first service provider network **102** with the destination address of the Local Session Proxy in third service provider network **402** as shown at state **808**. At step **810**, P2P interconnect control **202***a* may query the DNS server **302** to identify the name server address where the P2P interconnect control node **202***c* of the third service provider network **402** may be found. P2P interconnect control **202***a* may then contact P2P interconnect control **202***c* and query available routes to second communication device **108** as shown at state **812**. P2P interconnect control **202***c* may return routes including peering point **210***c* as shown at state **814**. Session controller **204***a* may then determine the path to peering point **210***c* as shown at state **816**. Communications may then be established between first communication device **106** and second communication device **108** at states **818** and **820**.

As noted above, embodiments of methods and systems for direct routing of communication sessions for mobile IP communication end points may be implemented or executed, at least in part, by one or more computer systems. One such system is illustrated in FIG. **9**. In various embodiments, system **900** may be a server, a workstation, a desktop computer, a laptop, a tablet computer, a mobile device, a smart phone, or the like. In some cases, system **900** may be used to implement communication devices **101** and/or **102**, and application server(s) **105** shown in FIG. **1**. As illustrated, computer system **900** includes one or more processor(s) **910**A-N coupled to a system memory **920** via an input/output (I/O) interface **930**. Computer system **900** further includes a network interface **940** coupled to I/O interface **930**, and one or more input/output devices **950**, such as proximity device(s) **103** (e.g., a Bluetooth® adaptor, a Wifi adaptor, or the like), keyboard **970**, and display(s) **980**.

In various embodiments, computer system **900** may be a single-processor system including one processor **910**A (e.g., processor **201** shown in FIG. **2**), or a multi-processor system including two or more processors **910**A-N (e.g., two, four, eight, or another suitable number). Processor(s) **910**A-N may include any processor capable of executing program instructions. For example, in various embodiments, processor(s) **910**A-N may be general-purpose or embedded processors implementing any of a variety of instruction set architectures (ISAs), such as the x86, PowerPC®, ARM®, SPARC®, or MIPS® ISAs, or any other suitable ISA. In multi-processor systems, each of processor(s) **910**A-N may commonly, but not necessarily, implement the same ISA. Also, in some embodiments, at least one processor **910**A may be a graphics processing unit (GPU) or other dedicated graphics-rendering device.

System memory **920** may be configured to store program instructions (e.g., algorithms for querying databases, accessing foreign service provider networks, etc.) and/or data accessible by processor(s) **910**A-N. In various embodiments, system memory **920** may be implemented using any suitable memory technology, such as static random access memory (SRAM), synchronous dynamic RAM (SDRAM), nonvolatile/Flash-type memory, or any other type of memory. As illustrated, program instructions and data implementing certain operations such as, for example, those described in connection with FIGS. **4-8**, may be stored within system memory **920** as program instructions **925** and data storage **935**, respectively. Additionally or alternatively, methods described herein may be implemented as a software program that is stored within system memory **920** and is executable by processor(s) **910**A-N. In other embodiments, program instructions and/or data may be received, sent or stored upon different types of computer-accessible media or on similar media separate from system memory **920** or computer system **900**. Generally speaking, a computer-accessible medium may include any tangible or non-transitory storage media or memory media such as electronic, magnetic, or optical media—e.g., disk or CD/DVD-ROM coupled to computer system **900** via I/O interface **930**. The terms "tangible" and "non-transitory," as used herein, are intended to describe a computer-readable storage medium (or "memory") excluding propagating electromagnetic signals, but are not intended to otherwise limit the type of physical computer-readable storage device that is encompassed by the phrase computer-readable medium or memory. For instance, the terms "non-transitory computer-readable medium" or "tangible memory" are intended to encompass types of storage devices that do not necessarily store information permanently, including for example, random access memory (RAM). Program instructions and data stored on a tangible computer-accessible storage medium in non-transitory form may further be transmitted by transmission media or signals such as electrical, electromagnetic, or digital signals, which may be conveyed via a communication medium such as a network and/or a wireless link.

In an embodiment, I/O interface **930** may be configured to coordinate I/O traffic between processor(s) **910**A-N, system memory **920**, and any peripheral devices in the device, including network interface **940** or other peripheral interfaces, such as input/output devices **950**. In some embodiments, I/O interface **930** may perform any necessary protocol, timing or other data transformations to convert data signals from one component (e.g., system memory **920**) into a format suitable for use by another component (e.g., processor(s) **910**A-N). In some embodiments, I/O interface **930** may include support for devices attached through various types of peripheral buses, such as a variant of the Peripheral Component Interconnect (PCI) bus standard or the Universal Serial Bus (USB) standard, for example. In some embodiments, the function of I/O interface **930** may be split into two or more separate components, such as a north bridge and a south bridge, for example. In addition, in some embodiments some or all of the functionality of I/O interface **930**, such as an interface to system memory **920**, may be incorporated directly into processor(s) **910**A-N.

Network interface **940** may be configured to allow data to be exchanged between computer system **900** and other devices attached to a network (e.g., telecommunications network **104** of FIG. **1**), such as other computer systems, or between nodes of computer system **900**. In various embodiments, network interface **940** may support communication via wired or wireless general data networks, such as any suitable type of Ethernet network, for example; via telecommunications/telephony networks such as analog voice networks or digital fiber communications networks; via storage area networks such as FibreChannel SANs, or via any other suitable type of network and/or protocol.

Input/output devices **950** may, in some embodiments, include one or more display terminals, keyboards, keypads, touchpads, scanning devices, RFID readers, NFC readers, voice or optical recognition devices, or any other devices suitable for entering or retrieving data by one or more computer system **900**. Multiple input/output devices **950** may be present in computer system **900** or may be distributed on various nodes of computer system **900**. In some embodiments, similar input/output devices may be separate from computer system **900** and may interact with one or more nodes of computer system **900** through a wired or wireless connection, such as over network interface **940**.

As shown in FIG. **9**, memory **920** may include program instructions **925**, configured to implement certain embodiments described herein, and data storage **935**, comprising various data may be accessible by program instructions **925**. In an embodiment, program instructions **925** may include software elements of embodiments illustrated in the above figures. For example, program instructions **925** may be implemented in various embodiments using any desired programming language, scripting language, or combination of programming languages and/or scripting languages (e.g., C, C++, C#, Java™, JavaScript™, Perl, etc.). Data storage **935** may include data that may be used in these embodiments (e.g., recorded communications, profiles for different modes of operations, etc.). In other embodiments, other or different software elements and data may be included.

A person of ordinary skill in the art will appreciate that computer system **900** is merely illustrative and is not intended to limit the scope of the disclosure described herein. In particular, the computer system and devices may include any combination of hardware or software that can perform the indicated operations. In addition, the operations performed by the illustrated components may, in some embodiments, be performed by fewer components or distributed across additional components. Similarly, in other embodiments, the operations of some of the illustrated components may not be provided and/or other additional operations may be available. Accordingly, systems and methods described herein may be implemented or executed with other computer system or processor-based configurations.

Although certain embodiments are described herein with reference to specific examples, numerous modifications and changes may be made in light of the foregoing description. Accordingly, the specification and figures are to be regarded in an illustrative rather than a restrictive sense, and all such modifications are intended to be included within their scope. Any benefits, advantages, or solutions to problems that are described herein with regard to specific embodiments are not to be construed as a critical, required, or essential feature or element of any or all the claims. Furthermore, it should be understood that the various operations described herein may be implemented in software, hardware, or a combination thereof. The order in which each operation of a given technique is performed may be changed, and the elements of the systems illustrated herein may be added, reordered, combined, omitted, modified, etc. It is intended that the embodiments described herein embrace all such modifications and changes and, accordingly, the above description should be regarded in an illustrative rather than a restrictive sense.

Unless stated otherwise, terms such as "first" and "second" are used to arbitrarily distinguish between the elements such terms describe. Thus, these terms are not necessarily intended to indicate temporal or other prioritization of such elements. The term "coupled" is defined as "connected" and/or "in communication with," although not necessarily directly, and not necessarily mechanically. The terms "a" and "an" are defined as one or more unless stated otherwise. The terms "comprise" (and any form of comprise, such as "comprises" and "comprising"), "have" (and any form of have, such as "has" and "having"), "include" (and any form of include, such as "includes" and "including") and "contain" (and any form of contain, such as "contains" and "containing") are open-ended linking verbs. As a result, a system, device, or apparatus that "comprises," "has," "includes" or "contains" one or more elements possesses those one or more elements but is not limited to possessing only those one or more elements. Similarly, a method or process that "comprises," "has," "includes" or "contains" one or more operations possesses those one or more operations but is not limited to possessing only those one or more operations.

The invention claimed is:

1. A method, comprising:

receiving, on a first service provider network, a request for access to a target communication device, the target communication device being associated with a second service provider network;

receiving, on the first service provider network, an indicator, from the second service provider network, that the target communication device is roaming on a third service provider network; and

establishing a peer-to-peer communication link with the target communication device on the third service provider network by a direct peer-to-peer interconnection process, in response to the indicator from the second service provider network that the target communication device is roaming on the third service provider network, by establishing a peer-to-peer communication session from a peering point in the first service provider network directly to a peering point in the third service provider network, that is associated with, and separate from, the target communication device.

2. The method of claim **1**, wherein the direct peer-to-peer interconnection process comprises:

referencing a list of available routes for peer-to-peer communication with the target communication device on the third service provider network;

identifying a path for communication with the target communication device in response to the list of available routes; and

establishing a peer-to-peer communication session with the target communication device over the path.

3. The method of claim **2**, wherein identifying the path for communication with the target communication device comprises:

obtaining default route information associated with a subscriber on a foreign service provider network in response to a request for route information, the default route information comprising identification of the peer-

ing point associated with the target communication device designated for peer-to-peer interconnection;

generating a directed query for additional peer-to-peer interconnection routes in response to the default route information;

obtaining one or more candidate routes from the foreign service provider network in response to the directed query; and

selecting one of the candidate routes for establishing a peer-to-peer connection with the subscriber of the foreign service provider network.

4. The method of claim **1**, wherein the peer-to-peer communication link is established directly between the first service provider network and the third service provider network.

5. The method of claim **1**, wherein a first peer-to-peer communication link is established between the first service provider network and the second service provider network, and a second peer-to-peer communication link is established between the second service provider network and the third service provider network.

6. The method of claim **1**, wherein a session control portion of the peer-to-peer communication link is established between the first service provider network and the second service provider network and a media path is established directly between the first service provider network and the third service provider network.

7. The method of claim **1**, wherein the indicator that the target communication device is roaming on the third service provider network is generated in response to a query of an active subscriber database associated with the second service provider network.

8. A tangible computer-readable storage medium having program instructions stored thereon that, upon execution by a computer system, cause the computer system to:

receive, on a first provider network, a request for access to a target communication device, the target communication device being associated with a second service provider network;

receive, on the first service provider network, an indicator, from the second service provider network, that the target communication device is roaming on a third service provider network; and

establish a peer-to-peer communication link with the target communication device on the third service provider network with a direct peer-to-peer interconnection process, in response to the indicator from the second service provider network that the target communication device is roaming on the third service provider network, by establishing a peer-to-peer communication session from a peering point in the first service provider network directly to a peering point in the third service provider network, that is associated with, and separate from, the target communication device.

9. The computer-readable storage medium of claim **8**, wherein the direct peer-to-peer interconnection process comprises:

referencing a list of available routes for peer-to-peer communication with the target communication device on the third service provider network;

identifying a path for communication with the target communication device in response to the list of available routes; and

establishing a peer-to-peer communication session with the target communication device over the path.

10. The computer-readable storage medium of claim **9**, wherein identifying the path for communication with the target communication device comprises:

obtaining default route information associated with a subscriber on a foreign service provider network in response to a request for route information, the default route information comprising identification of the peering point associated with the target communication device designated for peer-to-peer interconnection;

generating a directed query for additional peer-to-peer interconnection routes in response to the default route information;

obtaining one or more candidate routes from the foreign service provider network in response to the directed query; and

selecting one of the candidate routes for establishing a peer-to-peer connection with the subscriber of the foreign service provider network.

11. The computer-readable storage medium of claim **8**, wherein the peer-to-peer communication link is established directly between the first service provider network and the third service provider network.

12. The computer-readable storage medium of claim **8**, wherein a first peer-to-peer communication link is established between the first service provider network and the second service provider network, and a second peer-to-peer communication link is established between the second service provider network and the third service provider network.

13. The computer-readable storage medium of claim **8**, wherein a session control portion of the peer-to-peer communication link is established between the first service provider network and the second service provider network and a media path is established directly between the first service provider network and the third service provider network.

14. The computer-readable storage medium of claim **8**, wherein the indicator that the target communication device is roaming on the third service provider network is generated in response to a query of an active subscriber database associated with the second service provider network.

15. A system, comprising:

a first service provider network configured to:

receive a request for access to a target communication device, the target communication device being associated with a second service provider network;

receive an indicator, from the second service provider network, that the target communication device is roaming on a third service provider network; and

establish a peer-to-peer communication link with the target communication device on the third service provider network by a direct peer-to-peer interconnection process, in response to the indicator from the second service provider network that the target communication device is roaming on the third service provider network, by establishing a peer-to-peer communication session from a peering point in the first service provider network directly to a peering point in the third service provider network, that is associated with, and separate from, the target communication device.

16. The system of claim **15**, wherein the direct peer-to-peer interconnection process comprises:

referencing a list of available routes for peer-to-peer communication with the target communication device on the third service provider network;

identifying a path for communication with the target communication device in response to the list of available routes; and

establishing a peer-to-peer communication session with the target communication device over the path.

17. The system of claim **16**, wherein identifying the path for communication with the target communication device comprises:

obtaining default route information associated with a subscriber on a foreign service provider network in response to a request for route information, the default route information comprising identification of the peering point associated with the target communication device designated for peer-to-peer interconnection;

generating a directed query for additional peer-to-peer interconnection routes in response to the default route information;

obtaining one or more candidate routes from the foreign service provider network in response to the directed query; and

selecting one of the candidate routes for establishing a peer-to-peer connection with the subscriber of the foreign service provider network.

18. The system of claim **15**, wherein the peer-to-peer communication link is established directly between the first service provider network and the third service provider network.

19. The system of claim **15**, wherein a first peer-to-peer communication link is established between the first service provider network and the second service provider network, and a second peer-to-peer communication link is established between the second service provider network and the third service provider network.

20. The system of claim **15**, wherein a session control portion of the peer-to-peer communication link is established between the first service provider network and the second service provider network and a media path is established directly between the first service provider network and the third service provider network.

21. The system of claim **15**, wherein the indicator that the target communication device is roaming on the third service provider network is generated in response to a query of an active subscriber database associated with the second service provider network.

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